ARMY RESEARCH LABORATORY

Optimizing Collaboration in Battalion Staff Elements

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University of North Carolina
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Abstract

Increasingly, no single individual can acquire the varied and often rapidly expanding information needed to create and execute battle plans effectively. Collaboration between and among geographically dispersed and specialized individuals and teams throughout the command and control (C2) process will, in large part, determine battle performance. This study explores collaboration in C2 from a human information behavior perspective. Qualitative research methods, including document analysis of current and proposed military doctrine, interviews with experienced military officers, and observation of a C2 training exercise were used to discover characteristics of effective collaboration. Three dominant themes emerged from the data. The first finding focuses on the importance of an "interwoven situational awareness" where team members mutually develop an overlapping but not identical shared understanding of the battlefield. The second finding concerns a requirement for dense social networks or frequent communication between team members about the battle, the C2 process, and information that is specific to a battlefield function. The third finding highlights the need to expand the role of the signal officer to include an ability to customize human-computer interfaces for the staff, to develop and program information retrieval queries that reflect priority intelligence requirements, and to program automatic data transfers between and among higher, lower, and adjacent echelons. These results provide insights to the complex nature of collaboration and recommendations for further research with respect to training and technologies supporting C2.

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EXECUTIVE SUMMARY

Advances in technology have introduced an unprecedented level of complexity into many contemporary work settings within the military, industry, and academia. Information is driving the technological revolution. Increases in the amount and immediacy of information acquisition forces progress in dissemination and utilization technology. Within the military, battle command embodies information acquisition, dissemination, and utilization.

Technological and societal changes have altered the military strategy, leading to a vision based on mission diversity and technical specialization. Increasingly, no single individual can acquire the diverse and often rapidly expanding information needed to create and execute battle plans effectively. To be successful on the modern battlefield, individuals must work together to collect, integrate, and disseminate information throughout the command and control (C2) process. Successful collaboration between and among geographically dispersed and technically unique individuals and teams will determine battle performance. This study was designed to explore the relationship between changing battlefield requirements and organizational design.

The approach was to develop, validate, and refine a model or set of hypotheses that predict effective C2 organizational structures at the battalion level and factors that may influence these structures in the future. In model development, relevant U.S. Army doctrine and literature defining current and future or visionary practices were selected and analyzed. Emergent themes included the role of social networks as integral components of situational awareness; the need for systems analysis skills; and the importance of information flow between those planning the next battle and those executing the current battle. To validate the provisional model, data were collected by observations of simulated battle exercises and by interviews of experienced military personnel. Results are synthesized and presented by organizational structure, physical work locations, tasks, task execution and situational awareness requirements, communication and information behavior, and perceptions of quality and success. These categories and data were used to structure a review of the future of C2 and as a point of departure for proposing an organizational structure for C2 at the battalion level.

The complexity of C2 will grow as tasks that require higher level cognitive skills continue to replace performance of routine information gathering or mathematical processing skills. These more routine tasks, generally performed by assistants and aides, will most likely be performed by integrated information, decision support, and communications systems. The result will be the need for more C2 expertise, while an informal but effective on-the-job apprenticeship training

strategy will be eliminated. A new method must be identified to provide the staff officers with the experiences needed to become experts in C2. The use of high fidelity battle simulations may meet this requirement.

Battle simulation exercises must accurately reflect changing battlefield requirements. This means that actual battlefield information systems must be integrated into all training exercises and that individual staff officers and even pairs or groups of staff offices must become proficient at interacting with these systems to obtain the information needed to plan, prepare, or execute a battle and to maintain situational awareness. Training in human-computer as well as human-human-computer (collaborative) interaction tasks will be required. It is recommended that the role of the signal officer (SigO) be expanded to include skills and knowledge in the use and manipulation of information systems. The skills required in this position are similar to those skills provided in many master's level information science programs that include courses about telecommunications network systems, telecommunications protocols, information systems analysis, human-computer interaction, databases, programming, users' needs analysis, and collaboration.

A proposed organizational structure based on current and anticipated advances in technology and changing battlefield requirements is presented. This structure depends heavily on technical innovations. It assumes that systems such as the command and control vehicle (C2V) are adequate to support individual and team performance. The proposed structure is similar to the current structure without support personnel who are replaced by automation and staff officers who have expertise in the use of information systems. An alternate organizational structure is proposed as a means to transition from current capabilities to tomorrow's ideal environment. In the transitional organization, a SigO or information and communications systems specialist is assigned to each staff element or C2V to help develop, maintain, and operate the information and communications systems. By allowing for the introduction of several iterations of information and communications systems design, information systems will mature to require minimal technical knowledge to operate. In this manner, battlefield performance will be maintained at a high level. Staff officers will continue to have access to information throughout the transition and without having to become experts in the use and manipulation of information technology.

OPTIMIZING COLLABORATION IN BATTALION STAFF ELEMENTS

INTRODUCTION

It is commonly recognized that new visions of the battlefield are emerging. These visions include distributed communications and information systems that provide near real-time information dissemination capabilities that support planning, preparing, and executing battlefield operations in maneuver, intelligence, fire support, and logistics. The result is an increased battle operational tempo that must be supported by more responsive systems such as the mobile command and control vehicle (C2V) and the 21st century howitzer, the Crusader System. In addition, changes in the political climate within the United States and in the world place a greater reliance on synchronization between a smaller army with new, expanded, and diverse missions and joint and coalition forces (Training and Doctrine Command [TRADOC], 1994). These visions bring new challenges to command and control (C2). One such challenge is the increasing importance of collaboration[1] during the C2 process.

Increasingly, no single individual can acquire the diverse and often rapidly expanding information needed to create and execute battle plans effectively. Individuals must work together to collect, integrate, and disseminate information throughout the C2 process. They must collect, integrate, and disseminate several types of information, including information about the current battle situation, information about the C2 process, and specialized domain or technical information related to C2.

Information about the battle situation typically includes information about the mission, enemy, terrain or weather, troops, and time available (METT-T) (U.S. Army Command and General Staff College, 1995). It may also include information about obstacles, cover and concealment, observations, key terrain, and avenues of approach (OCOKA) as well as information about the political environment. This type of information is required input to the planning and operations process. Information about the C2 process includes information about C2 work practices, including tasks and task procedures, as well as knowledge about what information other staff members need or can provide, and how to effectively communicate with them and provide leadership, morale, support and encouragement. This information is required to participate in and manage the C2 process. Domain, or technical, information about battle strategies, weapon capabilities, telecommunications networks, decision analysis algorithms,

[1] Throughout this report, collaboration is defined as human behavior that facilitates the sharing of meaning with respect to a mutually shared superordinate goal and which takes place in a particular social, or work, setting.

civilian operations, biological chemicals, and so forth, is required to create, evaluate, and execute courses of action (COAs) on the battlefield. The number of technical disciplines and the amount of detailed technical information required in each discipline will undoubtedly continue to increase as the complexity and diversity of the battlefield increases.

The diversity in types of information implies that experts in a variety of areas must collaborate during the C2 process to effectively create and execute battle plans. These experts may come from different disciplines or specialties, different branches of the military, or even different countries. Furthermore, the content and nature of this collaboration will need to evolve and adapt to the battlefield of the future. Thus, it is essential to understand the characteristics of effective collaboration.

What are effective organizations for C2, given its collaborative nature and the vision of the future battlefield? This report discusses a preliminary study that addresses this question at the battalion level. Other research addresses current C2 practice (e.g., Harrison, 1995; McIlroy, 1995; Jarret, 1995; Knapp, 1996), and future C2 at higher echelons (e.g., EER Systems, 1996a, 1996b, 1996c, 1996d). We augment this previous research to develop a provisional model of organizational structures that supports effective collaboration at the battalion level for future C2 teams. The provisional model incorporates data from "real" C2 situations observed during a battlefield simulation and reported during interviews with experienced military personnel.

We conclude that C2 teams benefit when team members develop an interwoven pattern of situational awareness, including an understanding of the battlefield and of each other's awareness. For effective collaboration and performance, we suggest this awareness should span vertical and horizontal organizational levels as well as job specialties. The awareness need not be (and perhaps should not be) identical across individuals but should have some shared elements or knowledge. The second theme is the importance of social networks. Dense social networks, operationalized as frequent bi-directional information flow among team members, appear to contribute to team performance as perceived by team members. The third finding concerns a phenomenon called "contested collaboration" (Sonnenwald, 1995). When contested collaboration occurs, team members challenge the contributions of others. They may also maintain an outward stance of cooperation but work to further their own interests, at time sabotaging the collaborative effort. When this occurs, it hinders the achievement of the superordinate team goal.

Based on these results and information about future military policies and technology, we propose new job responsibilities and training to support collaboration in teams. Specifically, a model that identifies new tasks for C2 teams, new job responsibilities for signal officers (SigOs),

a new organizational structure for C2 teams, and a transitional organizational structure is proposed. Implications for training and future research to validate this proposal are also discussed.

These results may also be applicable to other information-intense organizations and dynamic situations. For example, the design and development process faces similar challenges and has similar attributes, as C2. Challenges faced in design and development include (a) distributed communications and information systems, including the use of multimedia, internet applications, and computer-supported cooperative work (CSCW) systems in a variety of domains, including product design; (b) a need for shorter design and development cycles to bring products to market more quickly in response to world-wide competition; (c) global collaborations that include international and multi-disciplinary expertise to create new, innovative products; and (d) a reduced work force who must deliver new products and services in a rapidly changing technical and political world. These are clearly analogous to challenges faced in C2. Design and development is also a collaborative process, as is C2. Design team members must collect, integrate, and disseminate information about the design context, information about the design process, and technical information from a variety of disciplines. The similarities between the types of challenges faced and types of information required imply that the results of this study may be extrapolated to other information-intensive organizations and dynamic situations such as design and development.

RESEARCH APPROACH

This study was conducted in three main steps: model development, model expansion, and model synthesis (see Figure 1). In the model development step, U.S. Army documentation about tactical operations centers (TOCs) and C2 was qualitatively analyzed, and a provisional model was developed based on that analysis. In the model expansion step, "real" C2 situations were examined using participant observation of training simulations and interviews with military personnel experienced in C2. These data were analyzed to refine and clarify the provisional model. In the model synthesis step, the C2 elements identified in the first two steps were compared and merged into a more general proposed model. The model is a set of hypotheses that predict effective C2 organizational structures at the battalion level and factors that may influence these structures in the future C2V scenario.

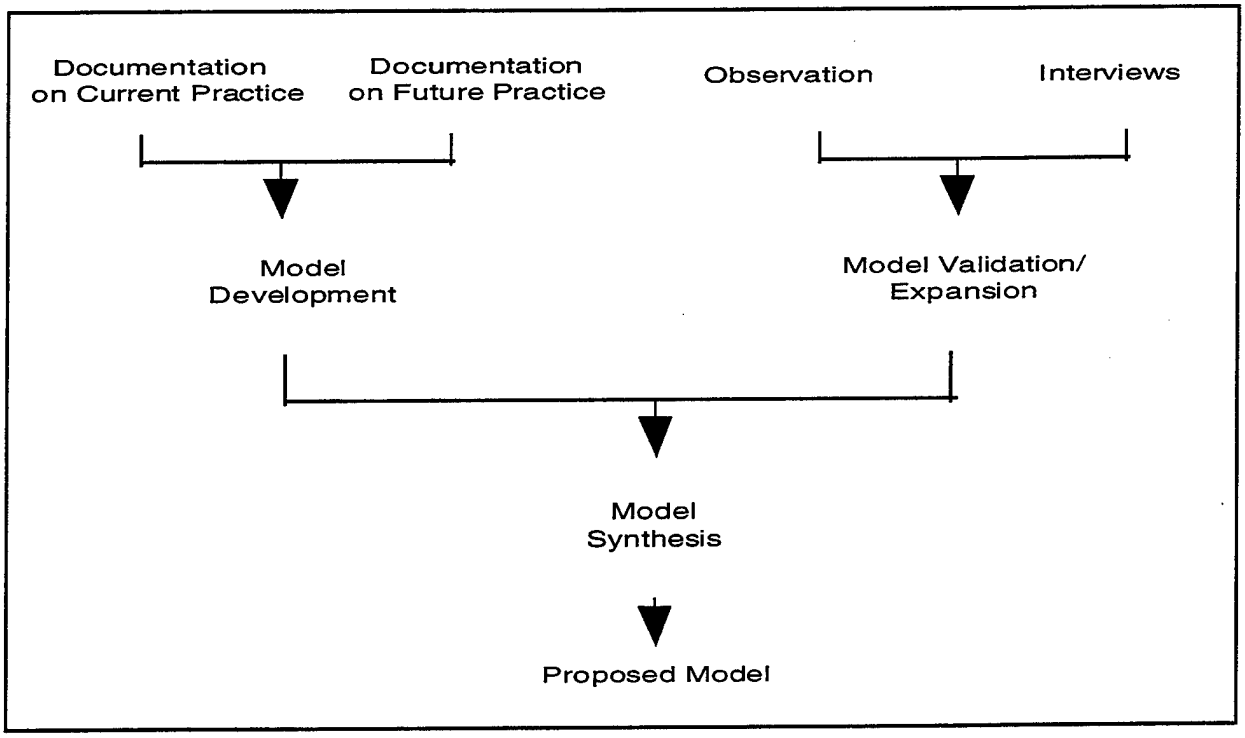

Figure 1. Research approach.

This approach allowed us to collect and synthesize formal and informal, current and retrospective data about C2. As illustrated in other studies (e.g., Sonnenwald & Lievrouw, 1996), this variety of information is highly appropriate and often required to understand the complexity and texture of information-intensive organizations and situations, such as C2.

Model Development

In the first phase, relevant U.S. Army doctrine and literature about C2 were selected and analyzed. Two categories of U.S. Army documentation were analyzed: current practice and future practice (as illustrated in Table 1). Current practice included (a) general doctrine that describes the overall battlefield organization and command processes, and (b) documentation of C2 tasks in TOCs. These documents provided a formal perspective of C2 on the battlefield of today. An awareness of the organization, goals, and tasks in current practice is required to develop hypotheses about C2 in the battlefield of the future because the hypotheses should, ideally, evolve from and augment current successes in C2.

Table 1

U.S. Army Documentation Used in Phase 1

Current Practice	
General	Battle Book (U.S. Army Field Artillery School, 1992)
	Battle Command: Leadership and Decision Making for War and Operations Other Than War (Battle Command Battle Laboratory, 1994)
	Command and Staff Decision Processes (U.S. Army Command and General Staff College, 1995)
	Operations, Field Manual (FM) 100-5 (Headquarters Department of the Army, 1986)
	Staff Organization and Operations, FM 101-5 (Headquarters, Department of the Army, 1984)
	Tactical Decision Making: Abbreviated Planning (U.S. Army Training and Doctrine Command, 1995)
Command and Control Tasks	Task Analysis for Plan for Combat Operations (Battlefield Function 18), (Harrison, 1995)
	Task Analysis for Direct and Lead Units During the Preparation for the Battle (Battlefield Function 19) (McIlroy, 1995)
	Task Analysis for Direct and Lead Units in Execution of Battle (Battlefield Function 20) (Jarrett, 1995)
	Modeling Maneuver Command Post: Task and Workload Analysis (Knapp, 1996)
Future Practice	
General intent	Force XXI Operations, Pamphlet 525-5 (U.S. Army Training and Doctrine Command, 1994)
	Staff XXI Concept (EER Systems, 1996)
	Combat Information Center (CIC) Concept (EER Systems, 1996)
Tasks at higher echelons	Expanded Development of the Staff XXI Concept: Staff XXI Reference Guide (EER Systems, 1996)
	Expanded Development of the Staff XXI Concept: Staff XXI Suggested Mission Training Plan Task Assignments (Second Draft) (EER Systems, 1996)
	Heavy Brigade Staff XXI Draft Tactics, Techniques, and Procedures (TTP) (EER Systems, 1996)
	Heavy Brigade Staff XXI Mission Training Plan (EER Systems, 1996)
C2V	Command and Control Vehicle (C2V) Heavy Variant TTP for Heavy Battalion, Brigade, Division, and Corps Command Posts, (Decisions and Advanced Technology Associates & EER Systems, 1994)
	Future C2V: Functional Assessment (Battle Command Battle Lab, USACAC, Ft Leavenworth, KS, 1993)
	C2V Operations (Reynolds, 1996)
	Task and Workload Analysis for C2V (Knapp, 1995)

The second category of Army documentation analyzed focused on another piece of the puzzle: future practice. Future practice documents included those that described (a) the general intent or vision of the military for the 21st century, (b) C2 tasks at higher echelons, and (c) C2V documentation. General intent or vision documents provided the high-level future perspective to guide the development of hypotheses. C2 at higher echelons was analyzed to ensure that hypotheses developed about C2 at the battalion level matched C2 at the brigade and division levels because C2 at these levels interact and should support each other.[2] Finally, C2V documentation was analyzed to ensure that hypotheses reflected as much as possible the advantages and constraints afforded C2 by the C2V environment—the environment in which C2 will take place in the 21st century.

This literature presented rather divergent perspectives. Yet, it seemed to share certain themes that might prove important when organizing battalion C2 staffs. These themes included the role of social networks as an integral component of situational awareness, the need for systems analysis skills, and the importance of information flow among planning and operations teams who create and execute.

Model Expansion

To determine the adequacy of the provisional findings, data from "real-world" situations were collected. The real-world data came from observations of a battlefield training simulation and interviews with military personnel from diverse backgrounds in C2 at the battalion, brigade, and division levels. The observational data were not from an actual battlefield situation per se because it was very impractical to observe an actual battle. However, the high degree of cognitive and emotional involvement of participants in simulations and the similarity of their behavior to behavior in actual situations have been observed in other studies. Furthermore, the unstructured and critical interview techniques used in this study have been shown to yield accurate accounts of people's previous experiences (Flanagan, 1954).

Observation of Battlefield Simulation Exercise

The battlefield training simulation exercise took place at the U.S. Army Field Artillery School Battle Simulation Center at Fort Sill, Oklahoma. The Depth and Simultaneous Attack Battle Lab and the U.S. Army Research Laboratory operate and use the simulation center for training and research. Janus, a two-sided, interactive, stochastic simulation used to simulate

[2] No documentation of future command and control practice at the battalion level was found.

battlefield forces and to stimulate information exchange and decision making within the command centers, was used to drive the training exercise. The observed exercise was performed at the end of the Officer Advanced Course. The students were field artillery captains who had been together in the training course for 6 months at the time of the exercise. They had participated in multiple field training exercises and three other Janus simulation exercises; several had also participated in other simulations. When asked, they replied they felt comfortable participating in simulations and had confidence in their ability to do so effectively.

In the observed exercise, the class was provided with higher headquarters operation orders, and students developed task force (TF)-level plans. The planning process includes analyzing the mission, creating and evaluating COAs, briefing the commander who selects a COA for execution, developing warning orders and operations orders (OPORDs) as needed, and briefing subordinates. After OPORDs have been created and subordinates briefed, the groups execute their plans during the Janus simulation. The Janus system allows them to execute COAs, including deploying scouts, providing fire support, and moving troops. Simulation Center personnel who execute COAs dynamically in response to students' actions play the enemy.

During the exercise, a researcher observed the air assault TOC team during their preparation for the battle, battle execution, and after-action review session. Interactions among group members, interactions between group members and higher and lower echelons, and interaction among other TF groups were observed. This group was selected because of their high level of performance of other tasks as reported by course instructors and their high degree of commitment to the exercise as observed by the researcher.

Adler and Adler (1987) define three roles the researcher may assume during participant observation: peripheral membership (the researcher interacts with participants but does not take part in activities central to the group); active membership (the researcher assumes functional roles in activities central to the group); and complete membership (the researcher "goes native," i.e., becomes immersed in the setting and becomes a full member). We chose the peripheral membership role to minimize the potential of the study to influence the participants' behavior and therefore to change the natural progression of the exercise. Thus, the researcher introduced herself and the purpose of the study to the participants but did not perform any tasks or offer advice to the participants during the exercise.

In the ethnographic tradition (cf. Lofland & Lofland, 1994), note taking was used extensively to record data. Exhaustive notes were made when events were observed during the

exercise. Later, away from the setting, these field notes were augmented with sketches of areas where the exercise took place; additional details about events and interactions, using the field notes as prompts; and summaries of overall impressions about events that occurred during the simulation.

Interviews

We also employed unstructured and critical incident interview techniques to gather additional data about C2 experiences. Seven interviews with experienced military personnel were conducted. Each interview participant had between 8 and 23 years of military experience. They had served in Desert Storm, Vietnam, Germany, Saudi Arabia, Korea, and the continental United States. At the battalion level, they had performed the duties of commander, S3 operations officer, assistant operations officer, S2 intelligence officer, fire support officer (FSO), SigO, S1 personnel officer, and S4 logistics officer. In addition to these positions at battalion level, they had also served as brigade FSOs, instructors at Army schools and colleges, General Staff and North Atlantic Treaty Organization Army group-level officers, and as operations research and systems analysts. Their experience came from maneuver, field artillery, signal corps branches, and the Army National Guard.

The interview process consisted of (1) an initial introduction that described the purpose and nature of the study, the anonymity or confidentiality of the participant's responses, and the participant's right to request clarification, to interrupt the interviewer, or to not answer questions; (2) the interview, where the researcher used an interview guide that contained a list of open-ended and critical incident interview questions and possible questions (see Appendix A); and (3) post-interview comments written by the interviewer, which captured her impressions of the interview (similar to additional notes generated after observation periods).

During the interview, non-directive and open-ended questions, or probes, were used to initiate face-to-face discussions with interview participants. These questions (see Appendix A) were used loosely to allow each respondent to shape the content of his or her answers. During actual interviews, additional questions, as needed, were used to clarify issues and concepts raised by participants. The first set of questions focused on the participant's military experience. The second set of questions focused on the participant's experience with C2 organizations. Each participant was shown a sample organizational chart of a battalion level TOC and was asked to compare the chart with his or her experiences in TOCs. The third set of questions focused on critical incidents. The critical incident technique, initially developed by Flanagan (1954), was used to collect additional self-report data about the participants' most

memorable positive and negative experiences in (battalion level) C2. This technique is especially useful for getting respondents to talk about conflicts and failures, which are often considered to be "private" in organizational cultures and not to be discussed with outsiders. Critical incident interviews allow participants to recall and describe events and conflicts in a fairly reliable way, with minimal impact on future interactions among colleagues (Kreps, 1991).

Each interview ranged from 1 to 2 hours; the average length was 1.5 hours. A combination of note taking and audio recording was used during the interviews. Audio recordings were transcribed.

These data were analyzed to discover the nature of C2 in battlefield situations and participants' perceptions of success and failure in C2. Although we developed a provisional model during the first step of the study, we did not attempt to refute or confirm that model here in the traditional scientific way. Rather, we attempted to understand the personal "models" of the participants, to derive our models from that understanding, and to validate them using the participants' perceptions as our main criterion.

Model Synthesis

The last step of our research was model synthesis. Here, we compared the models we had developed through the first two steps with other C2 models and devised a proposed model. This approach appears to reflect the multi-perspective nature and "art" of C2 better than any single-method approach. By looking at C2 from the multiple vantage points of documents, observation, and interviews, we may be more likely to discover a general model applicable across a range of situations.

Typical C2 Practice Today

From the qualitative analysis of documentation about current C2 practice, observation of C2 simulation exercises, and interviews with experienced military personnel, a picture of current C2 practice emerged. This picture characterizes participants and their work practices, particularly their organizational structure, physical work locations, tasks, task execution and situational awareness requirements, and communication and information behavior. It also describes individuals' perceptions of quality and success. The picture is a synthesis of individual stories about C2 as well as documentation on C2. It does not cover all variations of C2 practice. The Army culture encourages individuals to be creative problem solvers, using their own initiative to solve difficult problems as needed. This ideal is captured and reinforced in two

popular stories shared among Army personnel and told to the authors during interviews. As several participants explained,

> You will find historical examples where people followed the rules, did everything they were supposed to, yet failed. And you can find other examples of where they violated the rules and didn't fail. I mean, nobody told Hannibal that he couldn't get elephants over the Alps.
>
> We pride ourselves on being able to exercise initiative, judgment. These are valued commodities in our Army. You'll read little slides, or expressions, about German officers. There is a German officer, a general, who allegedly said that the American Army feels no compunction to follow its doctrine. In fact, they don't even read it. Therefore, they are very unpredictable. You just don't know what to expect from those guys. Even though they have this doctrine, they just behave differently.

Thus, it is not possible to describe all possible variations of C2 practice because individuals are creative problem solvers, and the Army culture encourages this creativity. It is nevertheless important to understand the typical practice of C2 today in order to build a vision of its future. The vision should incorporate the strengths of current practice and should address constraints of current practice when possible.

TYPICAL COMMAND AND CONTROL (C2) PRACTICE TODAY

Organizational Structure: C2 Personnel and Domains

C2 at the battalion level is performed by a team of experts in a variety of domains including leadership and management, military science, logistics, enemy intelligence, artillery (fire support), and telecommunications. These experts contribute to the C2 process in several ways. They explore and integrate their specialized knowledge to create plans that will accomplish the battle mission and intent and are achievable within the constraints of the situation. For example, their mission from brigade may be to take "Objective Eagle"; they must determine how best to achieve this goal. They also prepare for the battle, supervising personnel and performing tasks to support the battle plan and mission. In addition, they apply their expert knowledge to supervise and perform tasks during the battle, and they continually evaluate their units' performance and the situation to determine what additional tasks are required. Throughout these activities, they communicate and share information, ideally developing a shared understanding of the mission and battle and working in a coordinated fashion to achieve the mission. As one participant explained,

> They're information handlers. They're managing a knowledge base and that knowledge base allows them to develop an understanding of their situation and to assess within that understanding whether or not there's a problem. The second thing that they have to manage is decision making... The third...is actual implementation.

Personnel typically involved in C2 at the battalion level[3] are illustrated in Figure 2 and Appendix B. Usually, personnel are divided into three major groups: the command group, administrative logistics operations center (ALOC), and the TOC.

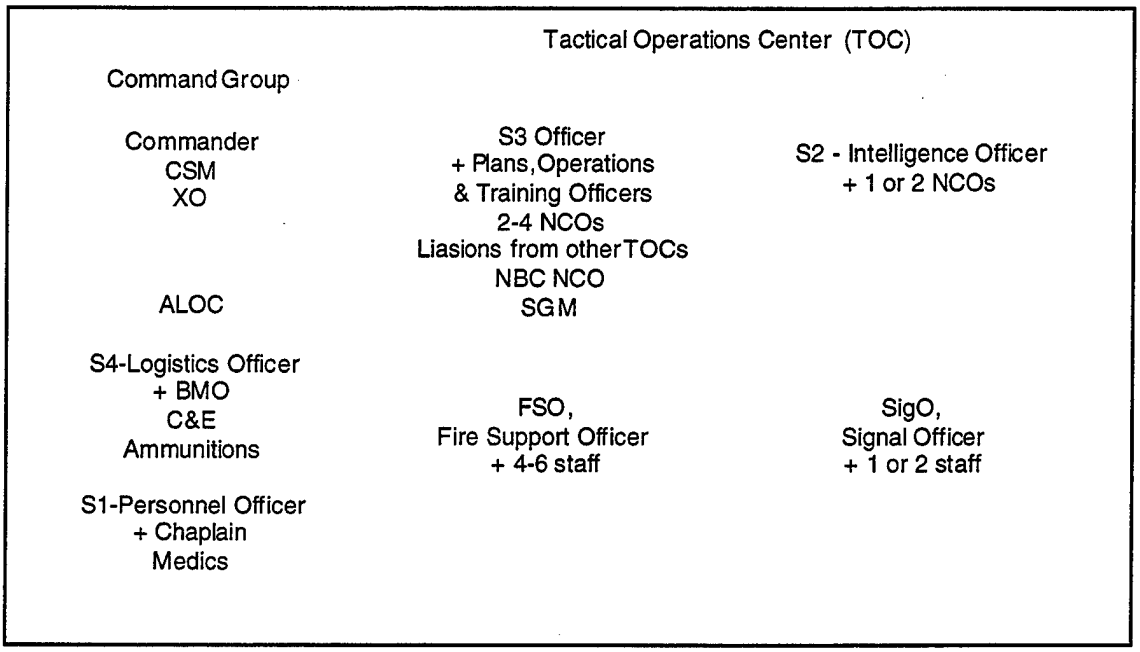

Figure 2. Typical domains and personnel in C2 at the battalion level.

Members of the command group include the commander, command sergeant major (CSM), and executive officer (XO). The commander assigns and gives the battlefield mission. He shares the mission and intent of the higher echelon (the brigade), evaluates and selects COAs, identifies critical information needs,[4] and provides leadership as needed throughout the C2 process. Leadership may include listening and teaching:

> [Another characteristic of] really effective C2 is when commanders are good listeners, and they ask good questions...good questions are teaching points and are also a way to elicit the type of information you need. Once I ask you the question, "where do you think the enemy's most dangerous course of action will be," three or four times, guess what happens? Pretty soon you are prepared to answer that question all the time.

[3] The battalion level generally consists of 300 to 1,000 soldiers organized into four to six companies. An overview of management levels in the U.S. Army is provided in Appendix B.

[4] These are often formalized as the commander's critical information requirements, which may include priority intelligence requirements, friendly forces information requirements, and essential elements of friendly information (Battle Command Battle Laboratory, 1994).

A list of specific tasks typically performed by commanders (and the other participants in C2) is provided in Appendix C. The CSM is often the "companion and confidant" of the commander with respect to the performance and operations of enlisted service men and women within his or her organization. The CSM is concerned with the morale, performance, and ethical behavior of enlisted soldiers. He or she has been described as the commander's "alter ego," and

> The guy that says, "Hey, we're having a problem with morality with the enlisted folks," or "Maybe you ought to deal with this particular individual because..." The CSM through his noncommissioned officer channels can say, "Look, now here's the real deal on the private. He's not going to tell you, so..." The CSM probably has more impact on the daily operations than the guy who is the commander or XO because the CSM's the guy the rest of the guys don't want to have to see."

The XO, however, is in charge of the ALOC (see Figure 3); for example, he ensures that the ALOC defense perimeter is adequate, their geographic dispersion is correct, they are prepared for the battle and will be prepared for the next move. He will also be called upon to command if the commander is not available. In some battalions, the XO may also supervise the S2 and SigOs, and the commander will supervise the S3 and fire support element (FSE) officers.

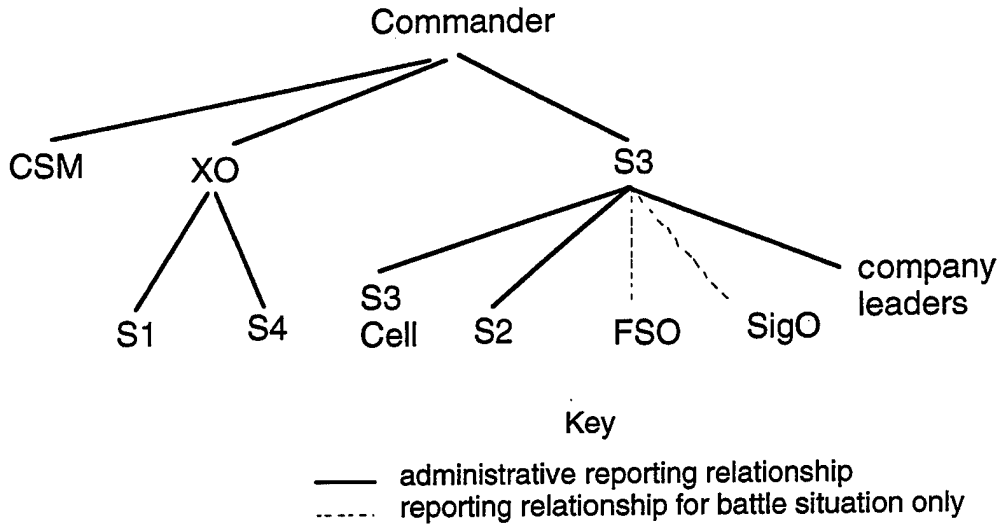

Figure 3. Prototypical C2 administrative reporting structure.

The ALOC group usually consists of the S4-logistics officer, S1-personnel officer, and a variety of staff that support their efforts.

> They're constantly monitoring various commodities and accounts, personnel accounts and supply categories. They're monitoring a set of personnel reporting instruments and logistics reporting to get clues as to how they can best support the commander and how to recommend the allocation of resources that are limited.

In particular, the S4 is responsible for "beans and bullets," that is, providing groceries, meals, equipment, fuel, ammunition, and mundane but necessary items such as portable toilets and cots. The battalion maintenance officer, ammunitions officer, and communications and electronics officer and their staffs are several of the important players who assist the S4. The S1 is in charge of personnel, including safety, filling vacated slots, assisting the injured, and handling captured enemy. A variety of medics, chaplains, and clerks usually assist the S1. The S4 and S1 also collaborate with the S3 and commander in planning and preparing for the battle to ensure that the companies will have the supplies, personnel, and personnel services when and where they are needed.

The TOC typically consists of four elements, including the S3 Plans and Operations, S2 Intelligence, FSO, and SigO. The S3 (who is often a major) is usually responsible for planning, including creating a series of alternate plans (COAs) and analyzing these alternatives with guidance from the commander and in collaboration with the S1, S2, S4, FSE, and SigO. The results of the planning and analysis are presented to the commander who will ask clarifying questions, possibly suggest refinements of the plan, and then select a plan. The S3 may also be responsible for supervising the preparation for the battle and execution of the battle[5]. In other words, "it's his show." As such, the S3 is responsible for creating situational awareness of the battlefield among the battalion staff and the companies that report to the battalion. He also needs to maintain an awareness of the logistics situation and how it may impact the battle and, perhaps, the civilians in the area. In addition, experienced S3 officers might also be considering future events. As one interview participant explained,

> The S3 should be working to be trying to deduce missions so he can keep the commander informed of what is happening, of what he expects might happen with respect to missions stated or unstated.

Two or three captains may assist the S3. These captains focus on plans, operations, and training and are often assisted by two to four noncommissioned officers (NCOs). The S3 may also be assisted by a sergeant major who provides detailed technical knowledge about the terrain and other aspects of the situation.

In addition, several other officers may be part of the S3 element. These include liaisons from other TOCs and nuclear, biological, and chemical (NBC) NCOs. The liaisons represent their TOC and help coordinate collaborative efforts between the two TOCs. As interview

[5] Alternatively, a battle captain (who may be the next ranking officer to the S3) may be in charge of executing the battle. However, no matter who is supervising the execution of the battle, the responsibilities remain the same.

participants noted, it may be very important that battalions understand the intent and mission of units on their flanks.

> Each guy is sending a member of his staff over to keep you posted on what's going on with respect to operations that may or may not have an effect on what you're doing. We do a lot with respect to these liaison officers to work toward the concept of a higher commander's mission.

In addition, battalions sometimes pass through each other's area; these passages must be well coordinated to avoid fratricide. The NBC officer is commonly referred to as the "bugs and gas" person; he is responsible for advising the S3 and commander about NBC threats.

Three other officers support planning and operations during the C2 process by collaborating with the S3 during the planning process and performing specialized tasks in preparation for and during the battle. These include the S2 Intelligence Officer, FSO[6], and SigO. These officers are usually captains or senior sergeants and are assisted by one, two, or four to six staff members. The S2 element is responsible for gathering and interpreting intelligence information about the enemy, including enemy equipment, enemy movement, estimates of enemy strength and locations, possible enemy targets, and the enemy's potential COA. The S2 also provides information about the weather and terrain.

> The S2 contributes in many ways. He is providing information on the enemy's order of battle and whatever we can learn about who our opponent is on the opposite side. How is he equipped? What is his doctrine? How can we expect him to behave in combat? [We use this information to devise] means by which to counter expected or anticipated activity, and [to devise] ways of depriving the opposing force [battle] capabilities.

The FSO plans fire missions and provides (or calls for) fire support during the battle. For example, the FSO must integrate knowledge about fire capabilities, ammunition status, enemy targets, the friendly situation, and troop movement, and geographic areas in creating and executing plans for fire. The FSO may report organizationally to another unit, for example, a field artillery unit. However, functionally, he and his staff are part of the TOC. A similar arrangement holds for the SigO and their staff. Organizationally, they may be part of the Signal Corps, but they function as an important component of the TOC. The SigO provides telecommunications support for the battalion. They may go into the battle area in advance to set up telecommunications networks, as well as work to maintain those networks and keep them secure during the battle. One participant proposed

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[6] In some battalions, the FSO will not be attached to the TOC but will be with its field artillery organization.

> You could, perhaps, look at the quality of the signal officer as a predictor of how effective C2 will be in that unit because most of the problems that we have are not difficult problems if you can communicate the vital information.

Occasionally, other elements may be assigned to the TOC as needed. For example, an engineering or air defense artillery unit may be assigned to help the battalion traverse obstacles (such as rivers) in the terrain or provide air artillery support, respectively.

Physical Structure

The TOC is usually the group located closest to the battalion companies on the battlefield. In particular, the S3 and S2 elements are generally located several kilometers from the front line. The elements operate from M577 command post vehicles that are usually positioned next to each other. As one participant explained,

> Whenever they pull into a field TOC, you can't wedge a piece of paper between the two vehicles. They've pulled together and put up a canopy tent extension that comes off both vehicles. That allows room to set up map boards and put some radios out there.

Co-location facilitates communication between the S3 and S2 elements. As one S2 described,

> Any plotting that we do on the map, if the S3 needs to know what's current, he can just step over here and look at the map and see where we are, or ask questions... we did the same...the way we kept updated [on the friendly locations] was by going over to the S3 map and getting those locations...if they were moving a battery usually you would overhear the S3 telling them to move so you would go over to find out where.

The FSE is often positioned away from the S3 and S2; it needs to be near the S3 shop to facilitate collaboration but separated for safety reasons.

> We try to separate them by 150m. The reason for this is that there's such a high amount of radio traffic among the S3, S2 and FSO vehicles that we don't want to get spotted by radio directional finding and get hit by incoming artillery. And if something does happen, we don't want everything destroyed at once. We want to have at least something, someone with some ability to take over.

The SigO may or may not be co-located with the S3 and S2. Often, the SigO needs to be nearby or at least available to the other elements in the TOC to monitor and maintain telecommunications services and keep them secure. However, the SigO may also need to travel through the battalion as well as monitor and maintain telecommunications services. As two interview participants explained,

> The TOC is a good place for him to hang his hat so if something was needed with respect to communication, we would know where he was.
>
> The SigO can often react quickest to problems in the field from the TOC. However, some SigOs may travel with ALOC personnel, checking on his company signal guys making sure they don't have technical problems.

The ALOC is typically located several kilometers away from the TOC and the predicted battle area. It is always farther back from the battle area. The ammunition depot, which is organizationally part of the ALOC, will usually not be co-located with the rest of the ALOC for obvious safety reasons.

The Command Group may be co-located with the TOC, in a separate tactical command post or close to brigade headquarters. Basically, the Command Group is "wherever they want to be....wherever they need to be to lead the effort."

Tasks, Task Execution, and Situational Awareness

A list of C2 tasks and the key personnel that participate in each task is provided in Appendix C. The list is derived from a series of task analyses performed by the U.S. Army Research Institute (Harrison, 1995; Jarrett, 1995; McIlroy, 1995) and augmented with data provided by interview participants. The majority of tasks (14/24 or 58%) require everyone's participation. An additional six tasks require participation by everyone except one person. Thus, 20 of 24 (or 83%) of the tasks require participation by everyone or everyone except one person. This is corroborated by interview participants who reported

> I don't believe that the COAs are necessarily an S3 product. It's the product of a team working together and I think that's going to include somebody from the ALOC, FSO, the S2 and the S3.
>
> Everyone plays a role—feeding or drawing information from the process.

Clearly, C2 tasks require a high degree of collaboration.

The sequence of these tasks is often portrayed as a sequential or cyclical process (see Figure 4). For example, the combat decision-making process, deliberate decision-making process, and quick decision-making process (TRADOC, 1995) illustrate the planning process as a series of interconnected sequential steps. The concept, planning or preparation, execution and assessment methodology (U.S. Army Command and General Staff College, 1995) and the headquarters effectiveness assessment tool (HEAT) process model (Buettner, 1985) portray the task sequence as a cyclic process, in which participants cycle through tasks. These models are excellent training

aids. They provide novices with clues about when to perform tasks. However, the sequence of steps proposed by the models appears not to be the norm in actual battles and exercises. One person described task execution as

> ...event driven and time dependent. It's kind of a double loop thing. It wraps around itself because as we implement, we're also in the process of planning for the next thing.

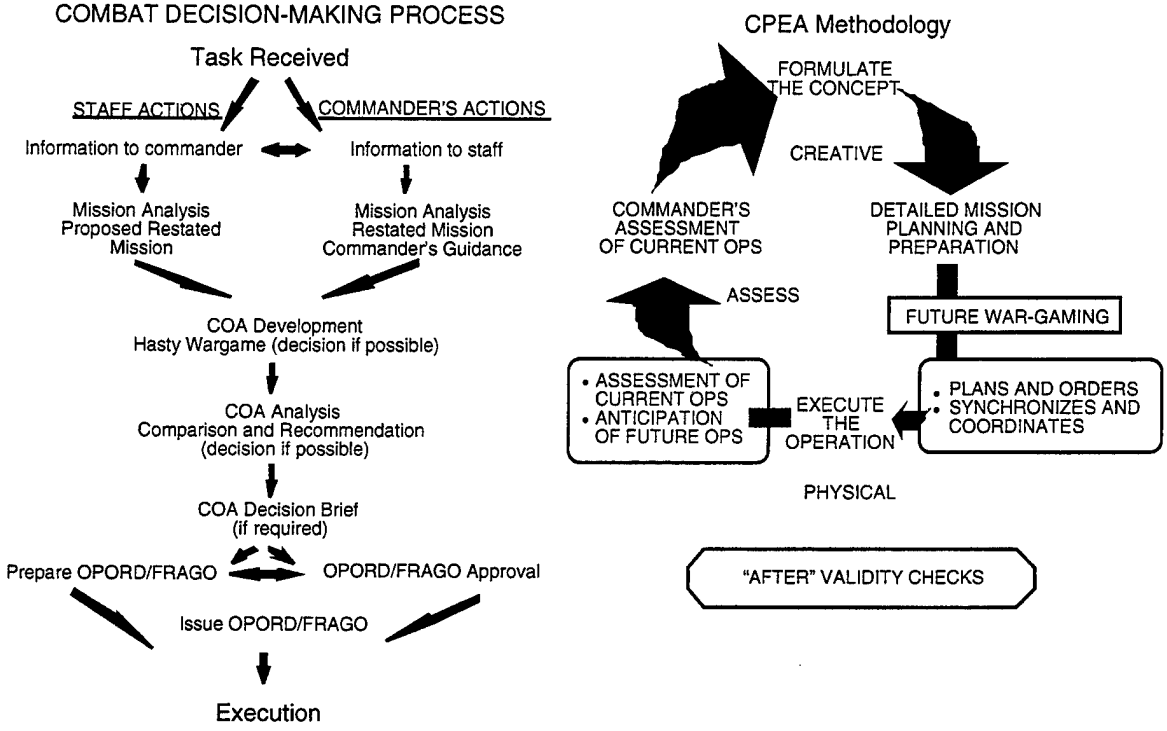

Figure 4. Examples of sequential and cyclic task execution methodologies.

The complexity and variety of battlefield situations imply that it is difficult (and perhaps impossible) to predict the sequence of C2 tasks accurately. This is discussed in the Army document, *Battle Command: Leadership and Decision Making for War and Operations Other than War* (Draft 2.1) (Battle Command Battle Laboratory, 1994) and by interview participants:

> When you start talking about C2, you start factoring in so many variables that are part of the process...it depends on the nature of individual officers...add to that physical factors...terrain...time.

It appears that the task phases, planning, preparation, and execution appear to begin sequentially and then continue in parallel (see Figure 5). Officers switch between planning, preparation, and execution tasks, based on their individual and shared understanding of the situation or situational awareness (see Figure 6).

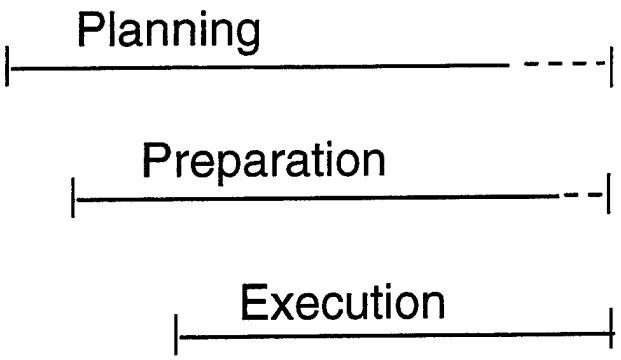

Figure 5. Major task phases in C2.

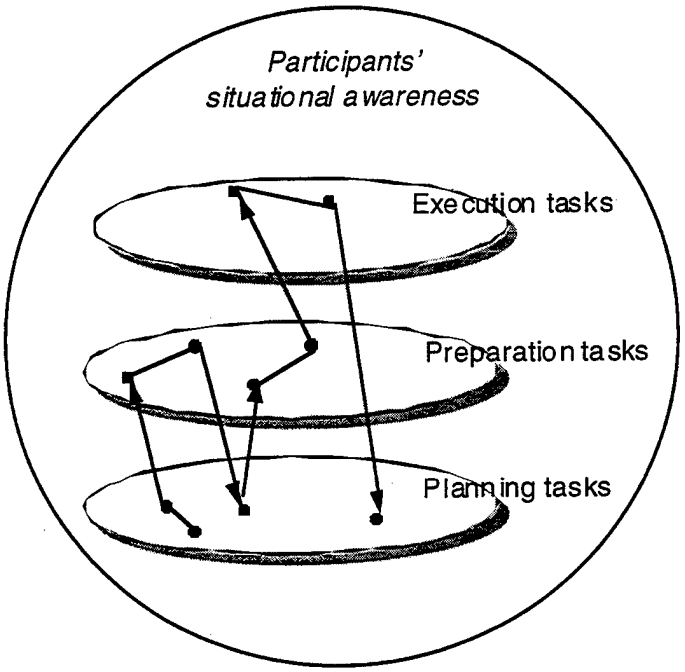

Figure 6. Task execution sequences.

Because so many of the C2 tasks are collaborative in nature, a common situational awareness appears to facilitate task completion. That is, participants monitor the situation, perceive changes in the situation, reflect on those changes, and select their next action, based on their reflection. This is analogous to the theory of perception proposed by Gibson (1979). Gibson proposed that humans "see," based on the eye detecting differences between objects. For example, we perceive a brown bug on a beige wall because we perceive differences in color and texture between the bug and the wall. Similarly, C2 personnel monitor the situation, perceive changes in it, and reflect on those changes to decide what task (or subtask) to perform (or not perform) next. As a result, participants may seldom perform C2 tasks in a sequential or cyclic

pattern. In fact, from the perspective of an outsider, their task sequence may appear erratic or irrational. As Simon (1981) points out, the bird's eye view of the ant's path from point A to point B across a sandy beach often appears irrational because the ant does not travel in a straight line. It is only when the context of the beach, including its peaks, valleys, and obstacles caused by grains of sand and items found on the sand, is considered does the rationale of the ant's path become clear. Similarly, it is only when the context of the battlefield is considered that participants' actions and task sequences become clear. Because of the complexity and variety of each battlefield situation, it is difficult to prescribe a definite task sequence.[7] Instead, personnel are encouraged to develop and maintain an individual and shared situational awareness (TRADOC, 1995) and based on that situational awareness, decide task sequences.

Situational awareness has been defined as

> Continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent mental picture in directing further perception and anticipating future events. (Vidulich, Dominquez, Vogel, & McMillan, 1994, p. 11)

Environmental information may include information about the mission (and intent), enemy, terrain/weather, troops and time available (METT-T); OCOKA; and ammunition and other resource levels and re-supply rates. Throughout the C2 process, participants collect, integrate, and reflect on this information and implications of the information. Because the amount of information for an entire battle situation is diverse and can be overwhelming[8], each individual, ideally, has a particular area and level of interest as appropriate for his or her job responsibility and job training. For example, an FSO is interested in information about fire capabilities, ammunition status, enemy targets, the friendly situation, troop movement, and geographic areas when creating and executing plans for fire, and so forth. In comparison, a SigO is interested in telecommunication transmission rates, antennae positions and directions, and switch connections. The commander is interested in the overall battle plan and plan execution. Thus, participants appear to develop an individual situational awareness that facilitates completion of their assigned tasks and job responsibilities.

In addition to developing their individual situational awareness, participants often—and perhaps always—need to develop a common or shared situational awareness. A common awareness is required to successfully complete the large number of complex and collaborative

[7] Part of the challenge in command and control research is to identify the complete set of contextual factors in battlefield situations, which influences tasks and how they influence tasks.

[8] Furthermore, the amount of available information is predicted to increase in the future because of the emergence of global information systems that can provide more information at faster rates.

tasks. The complexity and collaborative nature of tasks appear to imply that a common horizontal and vertical situational awareness is required (see Figure 7). A horizontal situational awareness may be necessary to effectively complete tasks that require collaboration across domains (at the same organizational level or abstraction level). As an interview participant explained,

> I think it's critical that these people (the XO, S3, FSO, S1, S4, SigO) all see a common picture of the battlefield...that they understand the temporal and spatial relationships about the objects on the battlefield and they understand how to enhance their effectiveness whether through positioning, through timing, through risk taking, through massing—a whole bunch of things like that. And I think the common understanding of the relative combat power of forces is pretty darn important when you get down to this level.

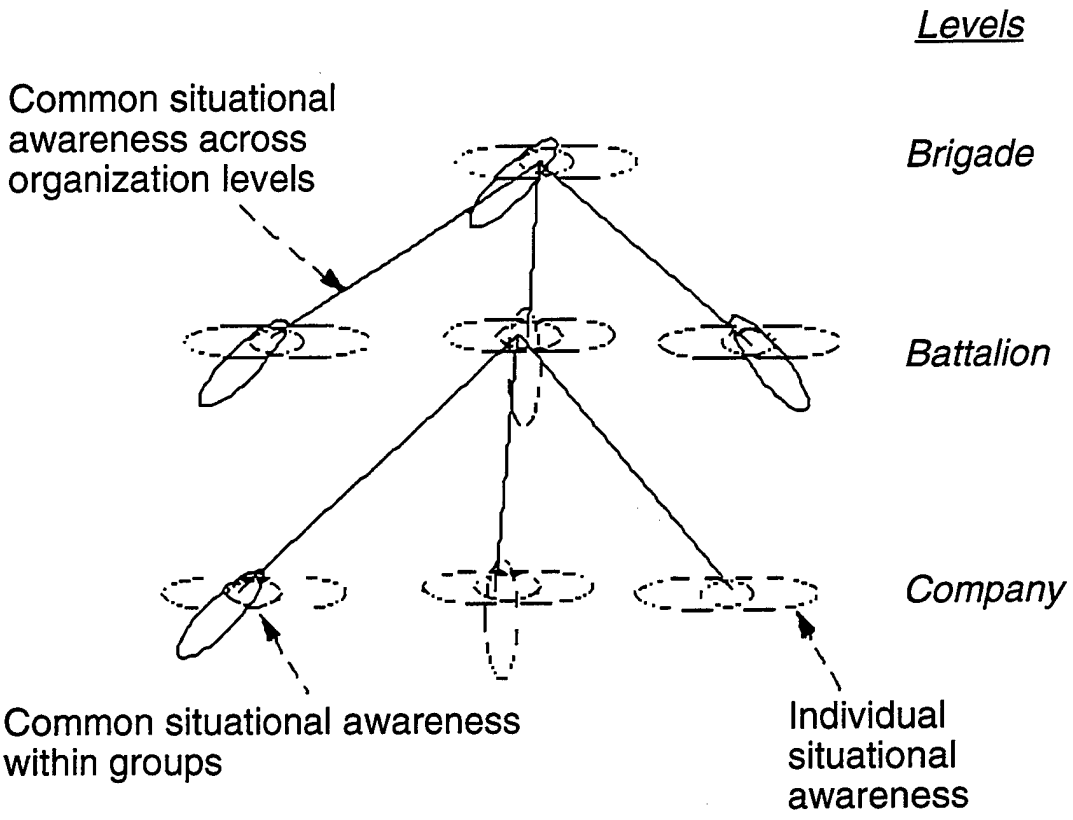

Figure 7. Individual and common situational awareness.

A common vertical situational awareness may be necessary to coordinate tasks across organizational levels (or abstraction levels). For example, the brigade commander (and staff) plans at a higher level of abstraction than the battalion commanders. However, the brigade and battalion commanders need to share some common understanding of the battle. Army documentation recommends that personnel understand the "higher (next higher and two echelons up) commander's intent, mission, purpose and end state." (Harrison, 1995, p. 32) Similarly, a battalion commander and company leaders must share some common understanding of the battle situation.[9]

No one individual can maintain a situational awareness that is common throughout all levels of abstraction or common across all domains. For example, a general cannot (and should not) maintain the same awareness of the battle situation as a soldier on the front line. The soldier feels and experiences the front line uniquely. However, both the general and soldier usually may perceive that they share some common understanding of the battle situation. Thus, a vertical and horizontal shared situational awareness appears to be required for effective C2.

Information Flow

Clearly, to create and maintain a common vertical and horizontal situational awareness, information must be communicated[10] among C2 personnel. The question is what information needs to be communicated to whom and when?[11] This is important when considering new organizational structures for C2 because the organization should be designed to facilitate this flow of information.

Three categories of information appear to be important in C2: information about the battle situation, the C2 process, and specialized domain knowledge. Information about the battle situation is analogous to the "environmental information" mentioned in the definition of situational awareness. It typically includes information about the METT-T (U.S. Army Command and General Staff College, 1995). It may also include knowledge about OCOKA as well as information about logistics and the political environment. This diverse information is

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[9] When this did not happen in the battlefield simulation exercise that we observed, maneuvers were not successful. At the start of the battle, company leaders dispatched troops without informing the S3 element. As a result, the S3 did not order artillery support (as had been planned) and causalities were incurred.

[10] Throughout this report, the term communication refers to human communication; the term communications refers to telecommunications.

[11] The information must also be communicated effectively, that is, in such a way that it changes people's situational awareness. Rehearsals (U.S. Army Command and General Staff College, 1995), including briefbacks, map rehearsals, and full rehearsals, are an effective communication strategy to help create a common situational awareness of the battle. A full discussion of communication strategies is outside the scope of this report.

explored and integrated to create and execute a comprehensive battle plan. Although the information may not necessarily be complete or 100% accurate, C2 participants must evaluate its validity and continue performing their tasks in the face of this uncertainty. Furthermore, the information usually changes throughout the C2 process. For example, as the battle progresses, the weather, terrain, and information about the enemy may also change.

Information about the C2 process includes (a) information about work practices, for example, tasks, formal task procedures (how tasks can be done), and informal task procedures (how tasks are really done in particular situations); (b) changes in the situation that require you to shift your focus of attention and change tasks (as illustrated in Figure 6); (c) information other C2 participants need or can provide; (d) effective communication methods; and (e) information about leadership, support, and encouragement. This type of information includes a variety of explicit and tacit knowledge pertaining to the C2 process and appears to be important. As one interview participant explained,

> I don't know if the quality of our planning or our planning horizons will be affected that much by the access to better quality or greater amounts of information about what's in front of us [on the battlefield]. The most important thing that allows you to command...is the ability to express clearly, to communicate clearly, your intent and what your expected outcomes are, and allowing your people to produce that outcome...providing enough latitude or flexibility in their execution so they have a reasonable chance to succeed.

This type of information is learned both formally (in classrooms and through reading) and informally through practical experience in C2 and "word of mouth."

Information from specialized domains or disciplines also appears to be required to perform C2. For example, information about battle strategies, decision analysis algorithms or methods, biological chemicals, telecommunications networks, civilian government, and so forth may be used or applied in any given particular battle context to the processes of creating and evaluating COAs on the battlefield. This type of information is often taught in colleges and is presented in textbooks (e.g., Student Text 101-5, *Command and Staff Decision Processes,* U.S. Army Command and General Staff College, 1995) and in computer applications such as decision support or risk analysis programs. The amount of detailed information in each domain and the number of domains will undoubtedly increase as emerging research results are applied to battle situations and the diversity and complexity of the battlefield increase to include digital technologies and a wider variety of peacekeeping situations.

Participants need information from all three categories of information at some point during the C2 process. Everyone needs information about the battlefield, the C2 process and their own roles in that process, and specialized domain knowledge. However, today the team is primarily organized along functional lines, that is, according to domain specialties. As discussed previously, the SigO element is primarily concerned with telecommunications, the S2 element with the enemy situation, the S3 element with operations and plans, the command group with leadership, the S1 element with personnel (or human resource) management, and the S4 element with logistics. Specific examples of information communicated between these elements are illustrated in Appendix D.

When a collaborative work approach is adopted by a TOC, an n-way communication network among elements emerges (see Figure 8). That is, each element interacts with all others. This often creates a synergistic and effective exchange and integration of information. An interview participant described an instance when this occurred:

> We all worked together. We were the best team. Everyone cooperated and understood their jobs. The S3 was open minded and willing to accept advice and information from outside his shop. The S2 was respected, and the S4 and S1 were strong people. Everybody realized there were limits we were working under and that we could also achieve the mission within these limits if we could modify the plans.

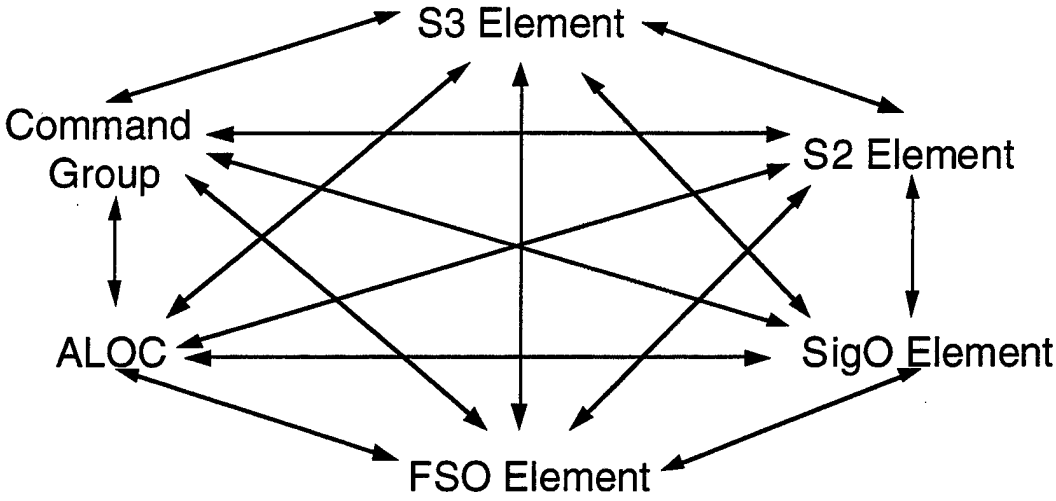

Figure 8. N-way collaborative network among C2 elements.

> Of course, such collaboration can be difficult to achieve due to time constraints, different expectations and conceptions of the C2 process, and differences in specialized languages or discourses. Sometimes, the S3 devises a grandiose plan autonomously, and then expects people to accomplish it. He doesn't realize that he doesn't have the necessary resources to achieve the plan...the S2 is left out because

> he was a lower officer. The S1 and S4 are left out because he expects them to execute whatever plan he develops. Sometimes resources just aren't there however.
>
> We argue constantly over definition of terms. What does 'destroy' mean? To artillery, it may mean 30% causalities; to someone else, it means everything dead. What does 'suppress' mean? What do you mean 'interdict'? We are constantly worried about how I define 'how do I achieve the commander's intent?' When the commander tells me what his intent is and my perception of what his intent is may be different form the guy sitting right next to me. I mean, our minds work like that. I can hear something that you don't hear.

In a worst case scenario, this may lead to the phenomenon referred to as "contested collaboration" (Sonnenwald, 1995). One situation was described as follows:

> We had no unity of effort. There were cross-purposes and misdirection, no coordination and it was a nightmare. It was crazy. It was insane.

In these situations, participants appear to maintain an outward stance of cooperation but strive to advance their own particular interests or information claims. For example, in the battlefield simulation exercise I observed, a company did not correct its erroneous report of a nearby enemy sighting. When discussing this among themselves, they rationalized that correcting the report would reduce their priority for fire support. They did not perceive (or did not care) that their priority status for fire support would negatively impact others who urgently needed fire support.

In these cases, the network that appears to emerge is a star configuration[12] (see Figure 9). The S3 or S3 element functions as a hub in the network. All information between nodes in the network is exchanged and filtered primarily through the hub. For example, information that the S2 element may have about enemy targets would first be sent to the S3 element and from there be passed to the FSO element. This configuration may change the rate of information dissemination. A time lag may be introduced, and the quantity and quality of information may be reduced. For example, information from the S2 to the FSO element may be delayed going through the S3 element. In other instances, that information may be lost (not transferred) or transmuted incorrectly when it is communicated.[13] However, in some instances, the message may be enhanced. This can occur when the hub has the ability to effectively translate between the

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[12] This configuration, or a variation of this configuration, may also emerge during stressful conditions, as has been found in Naval battle groups during battle exercises (Fehér & Rudolph, 1990). Further research is required to investigate this issue.

[13] This is similar to the phenomenon that occurs during the children's game "whisper down the lane" in which a message is whispered from one child to the next. The last child states the message out loud and the children are entertained by how much the message has been changed from the original version.

different perspectives and discourses in the nodes. This ability is primarily based on individuals' information processing and communication skills.

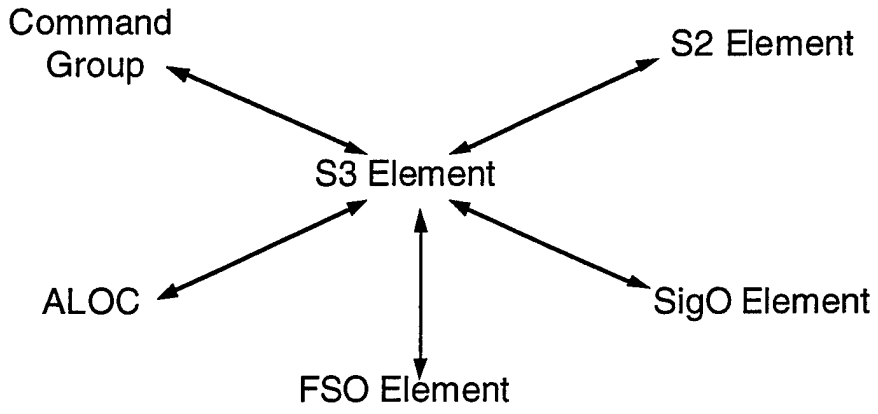

Figure 9. Star communication network configuration.

The typical external links in C2 at battalion level are illustrated in Figure 10. The external links are primarily divided along domain boundaries. The S2 communicates with brigade intelligence, the SigO with signal corps units, the FSO with field artillery units, and so forth. In external communication, then, personnel use and reinforce their specialized discourse or language and way of talking. For example, the SigO may use terms such as airborne data link, packet switch, residuals, shots, splice, footprints, and so forth. These terms have unique definitions within the telecommunications domain. Thus, C2 personnel must be able, to some degree, to switch between their specialized domain discourse and a collaborative discourse with other C2 participants. As a SigO explained,

> I translated information between the S3 and Signal Corps. They speak different languages. I also knew what information not to pass. I didn't send everything. Signal Corps didn't need to know what the S3 was planning (sometimes it's nice, but it's not necessary).

Information Flow During Continuous Operations

An additional factor that increases the complexity of information flow during the C2 process is the need to support continuous operations over several days or weeks. As one person exclaimed, "The enemy doesn't stop for chow at 5:00 p.m."

It is well documented that task performance degrades when soldiers do not have sufficient sleep. An average of 6 to 8 hours of sleep per night are required to maintain performance indefinitely, and 4 to 5 hours of sleep per night are required to maintain performance for 5 to 6 days (Battle Command Battle Lab, 1994). Thus, to support continuous operations over time, C2 personnel should work in shifts to enable all personnel to sleep on a daily basis.

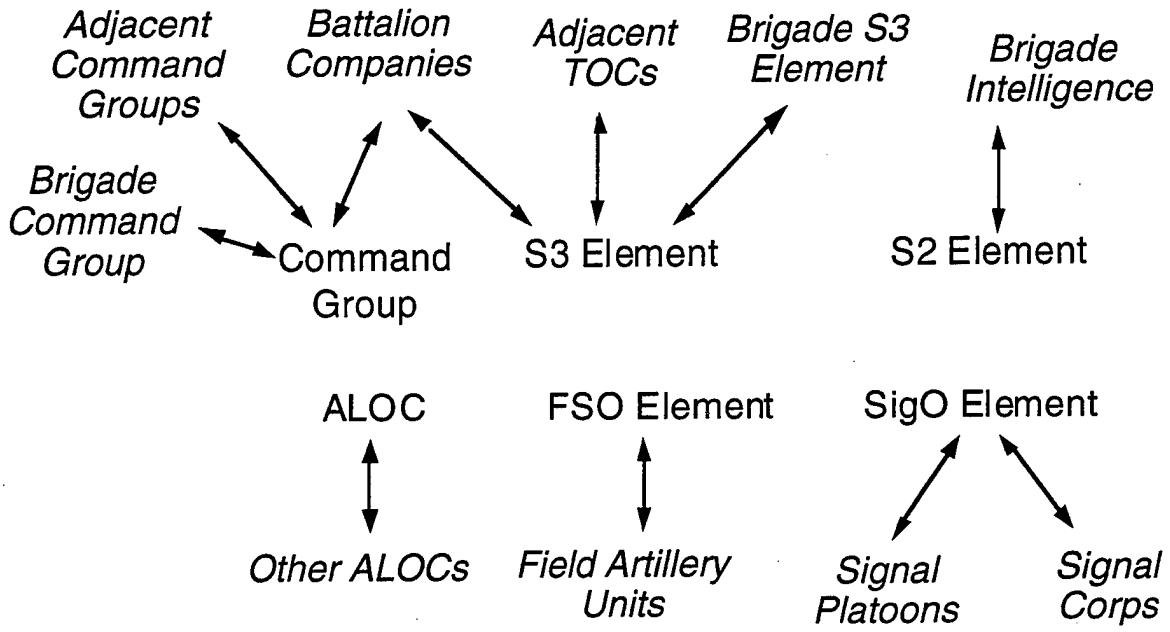

Figure 10. Primary external communication links.

However, battlefield conditions and Army culture make this difficult. For example, when TOCs are moving, no one sleeps because everyone is needed to assist in the move. Furthermore, as one person explained,

> If there's an attack at 5:00 in the morning, you can bet your bippy that everyone's going to be up and at it.

Interview participants also spoke of the "Iron Man" approach:

> In real life, most subscribe to the "iron man" theory and tough it out...in Desert Storm, some stayed awake the entire operation. This was possible because of its short duration. For a longer term, it's a lot tougher.
>
> There's an attitude that no matter who you are, there's no one who can do it as well as you.
>
> Even if you do have shifts, there's a degradation in quality. That's why a lot will "iron man" it.

During the best conditions, shift turnovers are difficult in information-intensive work settings such as C2. The team that has been working intensely together over the past 12 hours has had the opportunity to develop a shared situational awareness and understanding of the work and information flow. The personnel coming on board usually have not had this opportunity; they do not share a common situational awareness of the battle or understanding of the work and information flow because they have not had the opportunity to develop it together as a team. In addition, some interview participants reported that in practice, people working the "second shift" may even have less experience and lower skill levels. This increases the difficulty of shift turnovers and may put the mission in jeopardy.

To manage these difficulties, a variety of turnover practices has emerged. During the interviews, three practices (which we label the overlapping, change by levels, and interleaving strategies) were described. In the overlapping strategy, all personnel change shifts at the same time. Personnel work for 14 hours. They spend an hour at the beginning of their shift learning about the current status of the battle. Then, after working 12 hours, they spend an hour briefing their replacements. The briefing may be formally organized with the commander, XO, or S3 providing an overview of the battle situation, followed by a question and answer period. Alternatively, all personnel work together for 30 to 60 minutes in position, working the issues together. This strategy may be only minimally effective, however. No one interviewed thought this was an effective method; they reported a degradation in quality of C2 with this strategy.

A second strategy reported has a "change by levels" approach. In this approach, the NCOs rotate 2 hours before officers. This appears to provide some overlap in knowledge about the battle situation but does not fully address the issue of developing a common situational awareness of the battle or understanding of the work and information flow across levels in the organization.[14]

The third strategy, the interleaving strategy, is the most complex. In this strategy, parts of all shifts (or teams) are always on duty. Shift times are different for each element. For example, the S3 element might shift at 3:00, the S2 at 6:00, the FSO at 12:00, and so forth. The reported advantages of this approach included (a) no marked decrease in quality of C2; (b) soldiers in the field were less likely to notice personnel changes in C2 under this approach because communication did not change all at once; and (c) there was never a sudden lack of or no communication. The problems reported with this approach were logistic and cultural in nature.

[14] Furthermore, this strategy was ascribed only to exercise situations. It was not reported that it has been used in combat situations.

Getting people fed and awake at the right times was difficult, although not impossible, to work through. It was also difficult to get people to accept this strategy. In many maneuver battalions, people worked hard to be on the first team; being on the first shift was considered a reward for good work. This was altered under the interleaving strategy, and leaders were challenged to find other reward mechanisms.

Summary: Perceptions of Success

In summary, it is clear that C2 is a complex, information-intensive process that requires a collaborative effort among personnel from different domains and from different organizational levels. It is a difficult process to do successfully. When interview participants were asked to describe their most satisfying C2 experience, many responded with silence. The few who responded characterized successful C2 as follows:

> Well, you just have a good flow of information....Good information in a timely manner...It got to you [in a way that] it was effective. It was real clear. You had time to process it out to your guys and your guys had time to ask questions. They understood it.

> It's most satisfying when you don't notice it at all...Success is when you can fight the alligators at the other end of the pool and not worry about C2....Can't think of a single instance.

However, everyone interviewed easily provided an example of a dissatisfying experience. Stories of dissatisfying noncombat experiences focused on the (unnecessary) waste of staff resources. Stories of combat experiences focused on the lives that were threatened as a result. As we move forward, it is important to strive to augment the strengths of current practice and address challenges found in current practice and introduced by the future context of C2.

THE FUTURE OF C2

Advances in Technology and Army Doctrine

Advances in technology and Army doctrine[15] will help shape future C2 processes, including collaboration among future battalion staff elements. Anticipated changes include the introduction of C2Vs, digital battlefield systems, and the Staff XXI concept.

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[15] The nature of battle conflicts will also be changing to increasingly include joint force operations, multi-national forces, and operations other than war (TRADOC, 1994). However, the impact of these trends on command and control is outside the scope of this report.

The purpose of the C2V (Reynolds, 1996; Martin Marietta, 1993) is to provide C2 personnel with increased mobility on the battlefield to maintain close contact with their companies. The vehicle will include a driver and gunner in the front and room for four C2 personnel and their equipment in the back. Their equipment will include digital battlefield systems.

Future digital battlefield systems (EER Systems, 1996f) being developed include integrated information and telecommunications systems. The goal of these systems is to provide the C2 team with current and comprehensive information about the battlefield, advanced decision support aids, and communications capabilities with other groups, including their companies, and upper and adjacent echelons. For example, digital battlefield systems may replace the physical maps and charts used in C2 today with electronic maps and charts. These maps and charts may be integrated with decision support and planning tools that assist the team in creating and evaluating COAs. It has been proposed that the power and flexibility provided by the digital battlefield systems will allow C2 teams to be smaller in number— ideally, four people, the number that can work in the back of a C2V.

Army doctrine with respect to C2 is also undergoing changes. The architects of the Staff XXI Concept (EER Systems, 1996a, 1996b, 1996c, 1996d, 1996e) have proposed that C2 teams should employ a "cradle to grave" approach to planning and operations. That is, every team should create a battle plan, adjust (or prepare) for the plan, and execute the plan. Each of these steps would ideally take 4 hours and be done sequentially by a single team. At any given point in time, there should be three teams in action— one creating its plan, one adjusting its plan, and one implementing its plan.

When these proposed changes are considered, a picture of C2 in the future emerges. In this picture, each C2 team

(a) has four team members,

(b) works in a mobile C2V environment with advanced, integrated information and communications systems, and

(c) sequentially creates, adjusts, and executes a battle plan, each step taking approximately 4 hours. At any given time in each battalion, there will be three teams creating, adjusting, and executing different plans.

This future scenario will require teams and team members to collaborate in new ways. Team members' task, task execution, and situational awareness requirements will drive this collaboration. From these requirements emerge recommendations for a new organizational structure to support C2.

Future Task, Task Execution, and Situational Awareness Requirements

Bloom and colleagues (1956) proposed a taxonomy of cognitive skills. From low to high, this order includes (a) information, the recall of specifics; (b) comprehension, the ability to process information on a low level so that the information can be communicated without verbatim repetition; (c) application, the use of abstractions in concrete situations; (d) analysis, the breakdown of a situation into its component parts; (e) synthesis, the assembling of elements and parts to form a whole; and (f) evaluation, the making of judgments about the value of materials or methods. C2 tasks that require higher level cognitive skills, including synthesis and evaluation, will continue to be required and performed by C2 teams in the future. Examples of tasks that require higher level cognitive skills include analysis of operation orders from higher headquarters, creation of warning orders or fragmentary orders (FRAGO), development of COAs, implementation and evaluation of brief-backs and rehearsals, synchronizing tactical operations, directing the conduct of battle, evaluation of COAs, and so forth.

However, many subtasks or components of these tasks that require only routine information gathering or mathematical processing skills will most likely be performed by integrated information, decision support, and communications systems. For example, updating battlefield maps will ideally be performed automatically by communications and information systems. A company location or enemy sighting sent digitally through a communications system could be sent automatically to an information system that interprets and displays the information on an electronic map and notifies C2 personnel about the new information. This would eliminate the subtask of writing or placing pins on a map to display the information. Some information (such as pre-defined commander's critical information requirements [CCIRs] or priority intelligence requirements [PIRs]) sent digitally to a TOC could automatically be forwarded from the TOC to the commander if the communications and information systems were appropriately programmed. Similarly, pre-defined PIRs could be added to an information retrieval program that continuously searches available intelligence information databases for that information and forwards the results of those searches to the S2 automatically throughout the battle. Today, assistants and aides perform many of these types of tasks. In this scenario, these tasks will be eliminated. The elimination of tasks is required if the size of C2 teams is constrained to the

number of individuals (four) that will fit in the back of a C2V. However, this does not eliminate the need for the S2 and other officers. They will still be needed to analyze, evaluate, and synthesize the information.

Two implications of the elimination of routine tasks are important to note. Today, many staff members are trained via informal apprenticeships; working as apprentices (assistants and aides) in C2 teams, they "learn the ropes." This experience and knowledge, augmented by classroom learning experiences, helps them to become experts in C2. This training method will most likely be eliminated in the future as the routine tasks and positions are eliminated through digital battlefield systems. However, the "cradle-to-grave" approach to C2 will most likely require additional staff members who are experts capable of performing the higher level cognitive tasks in C2. In this scenario, the overall number of C2 staff may not decrease. There may simply be a shift of skill levels required in C2 teams; more skilled team members may be required. Thus, a paradox emerges. There may be an increasing need for additional experts on the battlefield while an effective training approach is eliminated. A challenge is to discover and implement effective new training methods to replace the apprenticeship training method that is disappearing. One solution to be investigated includes incorporating prototypes of the emerging communications and information systems into training simulations, such as Janus, as early as possible. This would provide personnel experience with these systems early and continuously during their formal training. It could also be used as an experimental platform to study C2 issues, such as task coordination and collaboration, at the group level and to provide additional feedback to the designers and developers of battlefield systems and Army doctrine.

The elimination of routine tasks also has an implication for the simulation of C2 teams using software simulation packages (e.g., see Knapp, 1995, 1996). In future simulation scenarios, the routine information gathering and mathematical processing tasks should, most likely, be modeled as human-computer interaction tasks. Of course, these assumptions should be verified as features and requirements of the proposed integrated communications and information systems emerge.

Task execution will, most likely, change in several significant ways. As mentioned previously, human-computer or human-machine interaction will become increasingly important in C2. All team members will need to interact with computer-based communications and information systems to complete their tasks. Thus, the critical nature of these systems and their

human-computer interfaces[16] will increase. Traditionally, C2 staffs have little or no training in human factors and human-machine interfaces. For example, in the C2 simulation exercise observed, participants had difficulty in choosing appropriate symbols to represent objects on maps. The "Red Army" was represented by silver pushpins; battalion companies were represented by red pushpins. This confused many team members throughout the simulation, and of course, the confusion increased during periods of heavy activity. Although more experienced staff may not make the same error, the error illustrates a common knowledge gap. As C2 teams increasingly use and rely on information systems, this knowledge gap becomes increasingly important. Therefore, we recommend that the SigO job be expanded to include skills and knowledge in information systems, including human-computer interaction. In this role, the SigO could customize human-computer interfaces for the staff, develop and program information retrieval queries that reflect PIRs, and program automatic data transfers between and among higher, lower, and adjacent echelons.

Additional tasks may include diagnosing and repairing problems that may occur in the communications and computer hardware and software throughout the C2 process; entering and transmitting COAs, warning orders, and FRAGOs; and executing software programs as requested by the S3. The skills required in this position are similar to those skills provided in many master's level information science programs in U.S. universities today (e.g., see University of North Carolina, 1996). These programs include courses about telecommunications network systems, telecommunications protocols, information systems analysis, human-computer interaction, databases, programming, users' needs analysis, and collaboration. The courses give students a broad background in information and communication systems. A broad background may be required when communications and information systems provide critical C2 capabilities to the battalion staff continuously throughout the C2 process.

Task execution may also evolve to include significant human-human-computer interaction. That is, when two or more team members collaborate, they may need to consult or interact with one or more information systems during their collaboration. For example, in developing a COA, two or more team members may wish to consult a decision-support system to assist in the analysis of COAs. In other situations, an S3 may request the SigO to search for particular information in available databases. Because information needs are often "fuzzy" and databases are precise, it can be difficult for the SigO to translate the S3's information need into a query statement that, when sent to a database(s), will provide the required information. In these

[16] See Norman (1988) for a detailed discussion of the importance of human-computer interfaces in successful task execution.

situations, the S3 and SigO may need to iteratively refine the query using feedback from the database to retrieve the required information. In still other situations, an S2 may wish to discuss his analysis of the enemy's most likely COA with the S3, and use an electronic map to help illustrate his analysis. Both the S2 and S3 may wish to temporarily highlight and move symbols on the map during the discussion. From these examples, two research questions emerge: (a) how can information systems be designed to support human-human-computer interaction, and (b) given the constraints of information systems, what strategies should team members use to effectively collaborate in these situations? These issues are beginning to be discussed in the research literature, particularly in the CSCW literature (e.g., see Thomas, 1996) and need to be addressed explicitly for the C2 context.

Today, situational awareness often includes a shared understanding among C2 staff from different backgrounds (or disciplines), among different levels in the Army hierarchy, and among adjacent units as discussed in the previous section, "Information Flow." Under the Staff XXI proposal, the requirements for and methods to achieve situational awareness will most likely change. A shared understanding among C2 teams who are simultaneously creating, preparing, and executing battle plans will need to be created and maintained throughout the battle. In many battlefield situations, plans change as they are implemented, sometimes in response to unanticipated events as they unfold or in response to new information. This flexibility in plan implementation can lead to battlefield success, and Army doctrine should continue to support flexible plan implementation. However, it implies that C2 teams who are simultaneously creating, preparing, and executing battle plans will need to share information and create a shared understanding of the battlefield.

For example, the team creating a plan may need to know how and understand why the plan being implemented has changed. They need to know how the plan has changed so they can augment the current COA. They need to learn why the plan has changed so they can create a plan that takes into account what caused the change(s) in the original plan. This implies that the team currently implementing a plan will have an additional requirement to share information with the teams creating and preparing plans. Further research is required to identify what information is required and how that information can best be communicated with minimal impact on the team executing a battle plan.

In other situations, teams creating or preparing plans for battle may wish to ask the team executing a plan specific information about the battle. This information (e.g., the team's remaining anticipated fire support needs) may not be available in databases, and the teams

planning and preparing for battle may need to ask the team executing a plan. Further research is required to identify conditions when teams creating and preparing plans should contact the team executing plans and how to contact them with minimal impact on current operations.

Another compelling reason to investigate situational awareness among teams creating, preparing, and executing plans focuses on shift turnovers and their impact on soldiers in the battlefield and the Army's "iron man" culture. We know that shift turnovers at the battalion level can be disruptive and difficult for companies (see previous discussion). The most effective approach to shift turnovers reported was the interleaving strategy of replacing different staff levels at different times. However, this approach will not be possible with four-person teams working and traveling on the battlefield in C2Vs. We need to understand how to create a shared situational awareness between the team preparing a plan and the team executing a plan and between the team executing a plan and the team preparing a plan, so as to minimize any negative impacts caused by shift turnovers between the two teams.

The "iron man" culture that encourages individuals to stay in C2 for as long as possible arose, in part, from a lack of trust that the replacement would perform as well. However, if individuals and their replacements shared a common situational awareness of the battle and understood that part of their job responsibility was to create such an understanding, individuals would perhaps be more willing to trust their replacements and relinquish control to them. Further investigation is required to test this hypothesis.

Organizational Structure

A possible organizational structure for C2 at the battalion level (see Figure 11) includes four TOC C2Vs staffed by S3, S2, FSO, and SigOs.[17] This group is similar to today's TOC but is limited to four personnel because the C2V and mobility requirements for C2 constrain the number of team members who can work together in a single physical location. However, the proposed digital battlefield systems that provide integrated information and communications systems for C2 are predicted to reduce the number of assistants and aides needed in C2 teams because the systems will ideally perform many of the subtasks and less skilled tasks required in today's C2 teams. Four such groups will most likely be required to implement the proposed "cradle-to-grave" approach to C2. After a battle begins[18], at any given point in time, one group will be creating battle plans, one will be preparing for battle, one will be implementing their battle

[17] The job responsibility of the SigO includes information and communications systems as discussed before.
[18] Before commencing operations, one group will be planning and others resting. As operations progress, one more group will be put in action until three are planning, preparing, and executing, with the fourth at rest.

plan, and one will be resting. If each of these phases last 6 hours, teams will be working on a 24-hour cycle and will receive sufficient rest. If each of these teams works 4 hours, they will be working at different times every day and will receive the minimum amount of rest recommended.[19]

Command Group	Tactical Operations Centers (TOCs)	
	C²V	C²V
C²Vs	*Creating Battle Plans*	*Preparing for Battle*
Commander	S3	S3
CSM	S2	S2
XO	SigO	SigO
	FSO	FSO
ALOC	C²V	C²V
C²Vs	*Executing Battle Plans*	*At Rest*
S4	S3	S3
S1	S2	S2
SigO	SigO	SigO
& Staff	FSO	FSO

Figure 11. Proposed C2 organizational structure (EER Systems, 1996f).

A minimum of four vehicles is recommended so that each team can customize its workspace, including the information and communications systems, to maximize its efficiency, and ideally not need to repeat that task during a battle period. In addition, the vehicle and its information and communications systems can receive maintenance and software and database upgrades in the time period when the team is resting.

C2Vs are also needed for the ALOC. The S1, S4, and a SigO could staff the C2V in conjunction with either a battalion maintenance officer, ammunition officer, or other subordinate. This would provide the S1 and S4 officers with the mobility to collaborate face to face with the S3, S2, and FSO officers during the battle planning and preparation phases. It would also provide

[19] At least 4 to 6 hours of sleep per 24-hour period are required for individuals to maintain high levels of performance (Battle Command Battle Laboratory, 1994).

them with the information systems and communications systems support they would need to complete their tasks, including communication with subordinates, the S3, or other team members when they are physically separated. For example, when plans needed to be modified during battle, the S4 officer could assist the S3 officer through sharing logistics information and performing calculations and decision making with respect to logistics to support the ongoing battle. A question is whether the ALOC C2V team should follow the same shift rotation as the TOC C2V teams. That is, should there be multiple ALOC C2V teams, each one collaborating exclusively (or primarily) with a particular TOC C2V team as it goes through the plan creation, preparation, and implementation phases? This approach may lead to a cohesive team with increased job satisfaction and job performance because they are an autonomous work group that has total responsibility for their mission (Eason, 1988). It would also enable the ALOC C2V to perform C2 tasks in emergency situations if the TOC C2V becomes disabled on the battlefield.[20] However, we need to investigate the impact of this approach on other logistical and personnel tasks.

A disadvantage of this organizational structure in general is its heavy reliance on technical innovations. It assumes that the C2V will provide an appropriate workspace that supports complex collaborative tasks, including critical thinking and human communication. The noise and motion of the vehicle may adversely affect task performance in ways we have yet to determine. Furthermore, it assumes that digital battlefield systems will eliminate the need for staff assistants and aides (see Beck & Pierce, 1996). If this is not possible in the first generation of C2Vs and digital battlefield systems, then a transitional organizational structure may be required.

A transitional organizational structure is illustrated in Figure 12. In this proposed structure, C2 is performed by four teams, each consisting of three groups in separate C2Vs. The S3, S2, and SigOs (as needed) would staff one C2V with an assistant or liaison from an adjacent unit. The FSO, information and communications systems specialist, and assistants would staff a second C2V or liaisons as needed. A third C2V would be staffed by the S1, S4, information and communications systems specialist, and assistants, as discussed previously. The role of the SigO and information and communications systems specialists in each C2V would be to help establish, maintain, and operate the information and communications systems. The SigO and information and communications systems specialists may actually input significant amounts of data and execute programs as requested by the other officers. It is anticipated that this job function may

[20] Of course, the S1 and S4 would also need to have training in command and control before going into battle to be effective emergency replacements. This training may have the added benefit of increasing the team's overall performance; cross-disciplinary training has also been shown to increase the overall effectiveness of multi-disciplinary teams (Volpe, Cannon-Bowers, Salas, & Spector, 1996.)

be required in each C2V until the systems are mature and require minimal technical knowledge to operate. Historically, when new information and communication systems have been introduced into work environments, several generations of improvements are required for systems to achieve their ultimate goal of staff reductions. This happens because it is difficult to anticipate and design for all conditions and contexts in which the system will ultimately be used.

For example, as one officer explained,

> Most of the time when things were going on, I would always have one of my clerks loaded with a headset dedicated to a particular frequency and that way I wouldn't be distracted. If something important came over the net, it was his responsibility to grab me by the collar and say, "Hey, sir! We have a hot one here!"

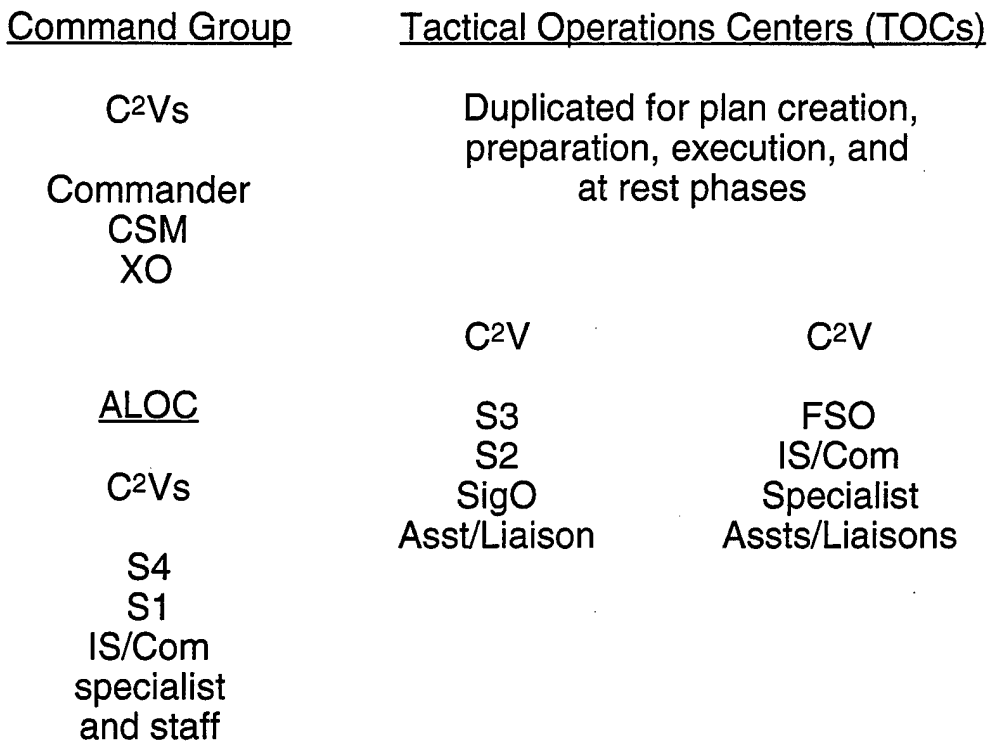

Figure 12. Proposed transitional organizational structure.

It may take several iterations of information and communications systems design and development to be able to provide this type of support effectively in the wide range of possible C2 situations.

CONCLUSIONS

This report presents a qualitative description of the C2 process. In addition to describing typical C2 organizational structure and physical structure, it provides insights into task execution, situational awareness, information exchange, and collaboration during the C2 process. We propose that task execution during C2 today occurs in concurrent phases of planning, preparation, and execution. The phases appear to begin sequentially but then occur in parallel. Task execution in the phases is often dynamic; that is, team members do not appear to perform planning tasks exclusively, followed by preparation tasks exclusively, and so forth. They often dynamically interleave planning, preparation, and execution tasks. This is important to understand when designing future integrated information and collaboration systems. Applications typically support planning, preparation, or execution tasks and are not integrated with one another. However, integration of these applications, allowing team members to dynamically change between task types and establish links between tasks as they do currently merits investigation.

We also highlight the need for situational awareness between organizational levels, across organizational levels, and within a C2 team. The types of information that data indicate must be shared to develop situational awareness includes information about the battle situation, the C2 process and specialized domain knowledge. N-way communication among C2 team members appears to yield better outcomes than a star configuration with information flow channeled primarily through one team member. Further research is required to understand in detail how these types of information can best be shared and used to develop situational awareness using new, emerging collaboration technology.

Another important issue in C2 is information exchange during continuous operations. In addition to the "iron man" solution, three approaches to shift changes were described by study participants: overlapping shifts, shift changes by level, and interleaving shifts. Interleaving shifts was identified as most effective. However, it is not clear if this approach can be implemented in a mobile battle situation as envisioned in Staff XXI.

Other challenges emerge when comparing the vision of Staff XXI, anticipated technology advances and current practice in C2. These include training, human-computer interaction, and human-human-computer interaction. We suggest there may be an increasing need to use simulations as a training mechanism and to include emerging technology applications in the simulations early in their development life cycle. This would help compensate for the elimination of low-level positions in C2 that are scheduled to be eliminated with the introduction of information and collaboration technology in C2 and would give valuable feedback to system

designers and developers. In addition, there may be an increasing need for C2 personnel to have information systems and human-computer interaction training. As information systems become more complex and integrated in the C2 process, on-site experts may be needed to customize and repair systems in the field. A further area of research is human-human-computer interaction. We suggest that in the field, higher level officers (e.g., commanders, S3) may not have time to interact with information systems directly but will rely on other personnel (e.g., S2) doing required information searches, and so forth. Important research questions include how personnel should be trained to facilitate this type of collaboration and how information systems can be designed to support human-human-computer interaction.

The report also describes a transitional and long-range organizational structure to support the Staff XXI concept. A key feature of these structures includes an information system specialist position. Research is required to test and refine these structures.

The areas of future research that emerged in this study seem to be centered on several common, fundamental issues: what are the observable team behaviors that affect productivity, and how can we evaluate these behaviors consistently? Without answers to these questions, we will not be able to evaluate new C2 work practices and/or technology. Therefore, we propose that future work include the development of (a) a taxonomy of C2 team performance functions that affect productivity; (b) a team performance task battery that evaluates performance of the team functions; (c) metrics that calibrate performance of the task battery; and (d) an automated team performance data collection software system that can be embedded in integrated information and collaboration systems in order to evaluate the systems. The task battery and metrics can then be used as a benchmark to test and refine new C2 organizational structures as well as information and collaboration systems.

In summary, this report provided insights into C2 practice. It discussed the typical C2 organizational structure and tasks from the perspective of experienced personnel, trainees, and Army doctrine. It identified new aspects of situational awareness and information flow that appear to be important for successful C2, as reported by experienced C2 personnel. Through an understanding of current C2 practices and information about anticipated changes in technology and Army doctrine, changes in task, task execution, and situational awareness requirements were identified. Based on these changes, a transitional and a future organizational structure for C2 at the battalion level were proposed. Future research is required to test the proposed future organization. Additional research issues were identified in the areas of situational awareness, training, and human-human-computer interaction. To begin to address these issues, we must first understand the fundamental and observable team behaviors that affect team performance.

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APPENDIX A

INTERVIEW GUIDE

INTERVIEW GUIDE

Nondirective questions were used to initiate face-to-face discussions with interview participants. During actual interviews, other questions were used to elaborate on issues and concepts raised by participants. It is important for the interviewer to be flexible and sensitive to the situation and the shifting focus of the respondent; questions, or probes, were used loosely to allow the respondent to shape the character and contour of an answer.

In the list of questions below, follow-up questions are enclosed in parentheses; generic terms that were substituted with relevant terms are denoted by square brackets; and similar phrases, one or more of which was used during interviews, are separated by slashes.

After introducing myself and the study, the first set of questions used during the interview focused on their Army experience and included questions such as

How many years have you been in the Army?

What is your current position/job?

What has been your battlefield experience? (What was your position/task then? When did this occur? For how long?)

The second set of questions focused on participant's experience with C2 organizations. Each participant was shown a sample organizational chart of a battalion level TOC and asked to compare the chart with their experiences in TOCs. In particular, the following questions (and variations of these questions) were asked:

Is the organization shown in this chart similar to ones you worked in? (What is the same? What is different? What is missing?)

What were your responsibilities as FSO/S3/S2/etc.? (Who did you interact with? Why?)

Who did the planning? (Who did they interact with when creating the plans? When would this interaction occur?)

Who executed the plans? (What was the typical interaction between those planning and those executing the plans?)

At the battalion level, did people create plans for the sequel to the future operations? (Who? When? Who did they interact with?)

Can you give me examples of how shift turnovers were done?

The third set of questions focused on critical incidents. That is, the critical incident technique, initially developed by Flanagan (1954), was used to collect additional self-report data

about the participants' most memorable positive and negative experiences in (battalion-level) C2. Open-ended questions focused on the respondents' experiences of effective and ineffective task and communication behavior related to a specific event, or critical incident, in C2. This technique is especially useful for getting respondents to talk about conflicts and failures, which are often considered to be "private" in organizational cultures, and not to be discussed with outsiders. Critical incident interviews allow participants to recall and describe events and conflicts in a fairly reliable way, with minimal impact on future interactions among colleagues.

> What was your most satisfying C2 experience? (Please describe it in detail. What happened? What was the situation? Who did what? Who spoke with whom? How did they communicate? What did they communicate, and how frequently? What made this event successful?)
>
> What was your most dissatisfying C2 experience? (Please describe it in detail. What happened? What was the situation? Who did what? Who spoke with whom? How did they communicate? What did they communicate, and how frequently? If you could have changed anything about the collaboration among your colleagues and staff in this situation, what would you have changed? Why? What made this event unsuccessful?)

APPENDIX B

GENERAL STRUCTURE OF ARMY FORCES

GENERAL STRUCTURE OF ARMY FORCES

The general structure of U.S. Army forces is illustrated in the following table. The primary focus in this report is on the battalion level. The battalion generally consists of 300 to 1,000 soldiers organized into four to six companies.

Organizational level	**Soldiers**
Squad/section	9 to 10
Platoon (two to four squads)	16 to 44
Company/battery (three to five platoons)	62 to 190
Battalion/squadron (four to six companies)	300 to 1,000
Brigade/regiment/troop (two to five battalions)	3,000 to 5,000
Division (three brigades)	10,000 to 15,000
Corps (two or more divisions)	20,000 to 45,000
Army	50,000

APPENDIX C

LIST OF C2 TASKS

LIST OF C2 TASKS

The following table of C2 tasks and key participants is derived from the series of task analysis performed by the U.S. Army Research Institute (Harrison, 1995; Jarrett, 1995; McIlroy, 1995). The term, *all,* is used to designate all personnel discussed in the section entitled, "Personnel and Their Responsibilities." In some instances, the list of key participants was updated to include information provided by experienced military personnel. For example, the list of participants in the task "consolidate and reorganize" done during the execution phase was updated to reflect comments that the SigO would often participate in this task.

Task phase/task	**Key participants**
Planning for battle	
Direct and lead battalion during planning	All
Receive orders from higher headquarters	Commander, XO, S3 section representative, S2 section representative
Conduct mission analysis	All
Issue the warning order	XO, S3 or representative, S2 or representative
Commander issues guidance	All
Prepare staff estimates	All
Staff develops COA	All (except commander)
Staff/commander analyze COA	All
Staff compares COA	All (except commander)
Commander announces decision	All
Staff prepares OPORD/FRAGO	All (except commander)
Issue the OPORD/FRAGO	All
Refine the OPORD/FRAGO	All (except commander)

Preparation for battle	
Acquire and communicate information and maintain status	All
Assess situation; visualize the battlefield	All
Determine actions; commander directs changes to the operation or plan	All (except CSM)
Commander directs and leads subordinate forces	All
Cells locate where they can control the preparation and transition to battle	Commander, XO, S3, "Battle Captain," S1, S4, SigO
Execution and supervision of battle	
Acquire and communicate information and maintain status	All
Assess situation; visualize the battlefield	All
Determine actions; commander directs changes to the operation or plan	All (except SigO)
Commander directs and leads subordinate forces	Commander, CSM, XO, S2, S3, FSO
Cells, or elements, locate where they can control the preparation and transition to battle	All
Consolidate and reorganize	All

APPENDIX D

INFORMATION FLOW IN C2

INFORMATION FLOW IN C2

The following table is derived from Army documentation (Harrison, 1995; Jarrett, 1995; McIlroy, 1995) and interviews with experienced military personnel. In the table, the terms, S1, S2, S3, S4, FSO and SigO, are used as shorthand for the S1 element, S2 element, S3 element, and so forth.

Communication path		
From	**To**	**Examples of information communicated**
Command group	Every element	Mission and intent; information requirements; high payoff and priority targets; critical tasks; COA; CCIR, including PIR, friendly forces information requirement, and essential elements of friendly information; guidance in their specialty;
Every element	Command group	Status updates; CCIR; potential problems; understanding of mission; relevant information from their specialty; COA
S3	Command group	COAs; anticipated events; CCIR
S3	Every element	COAs; OPORD; FRAGO; warning orders; status; morale/support
Every element	S3	Understanding COA; status; changes; relevant information from their specialty
S3	S2	Friendly situation
S2	S3	PIR; intelligence information including enemy locations, strength, movement, potential targets, potential COAs; weather (sunrise, sunset); terrain
Every element	SigO	Communications problems
SigO	Every element	Communications capabilities; security codes
S2	FSO	Possible targets
S3	FSO	Targets (timing); friendly situation
FSO	S3	Fire capabilities; fire results
S3	S1	Personnel requirements; including anticipated casualties, injuries
S1	S3	Personnel information, including troop strength

From	To	Examples of information communicated
S2	S1	Captured enemy
S3	S4	Logistics requirements
S4	S3	Logistics, including status of supplies such as fuel, food, ammunition, and resupply rates
brigade FSO	FSO	Fire planning
brigade Intelligence	S2	Intelligence information
Signal Corps	SigO	Technical communications information
SigO	Signal Corps	Technical communications problems
SigO	Other TOCs	Security clearance
SigO	Companies	Communications capabilities
Companies	S2	Locations
S3	Companies	OPORD; FRAGO; warning order; COAs; morale/support
Companies	S3	Understanding COA; status including location, results of actions, enemy response; CCIR
TOC	Other TOCs	Flank coordination information
Other TOCs	TOC	Flank coordination information
TOC	brigade (higher echelons)	Coordination

APPENDIX E

ACRONYM LIST

ACRONYM LIST

Acronym	Definition
ALOC	administrative logistics operations center
C2V	command and control vehicle
CCIR	commander's critical information requirement
CIC	combat information center
COA	course of action
CSCW	computertosupported cooperative work
CSM	command sergeant major
FM	field manual
FRAGO	fragmentary order
FSE	fire support element
FSO	fire support officer
HEAT	headquarters effectiveness assessment tool
METT-T	mission, enemy, terrain or weather, troops and time available
NBC	nuclear, biological, and chemical
NCO	noncommissioned officer
OCOKA	obstacles, cover and concealment, observations, key terrain, and avenues of approach
OPORD	operations order
PIR	priority intelligence requirement
S1	personnel officer
S2	intelligence officer
S3	planning and operations officer
S4	logistics officer
SigO	signal officer
TOC	tactical operations center
TRADOC	Training and Doctrine Command
TTP	tactics, techniques, and procedures
XO	executive officer

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13. ABSTRACT *(Maximum 200 words)*

Increasingly, no single individual can acquire the varied and often rapidly expanding information needed to create and execute battle plans effectively. Collaboration between and among geographically dispersed and specialized individuals and teams throughout the command and control (C2) process will, in large part, determine battle performance. This study explores collaboration in C2 from a human information behavior perspective. Qualitative research methods, including document analysis of current and proposed military doctrine, interviews with experienced military officers, and observation of a C2 training exercise were used to discover characteristics of effective collaboration. Three dominant themes emerged from the data. The first finding focuses on the importance of an "interwoven situational awareness" where team members mutually develop an overlapping but not identical shared understanding of the battlefield. The second finding concerns a requirement for dense social networks or frequent communication between team members about the battle, the C2 process, and information that is specific to a battlefield function. The third finding highlights the need to expand the role of the signal officer to include an ability to customize human-computer interfaces for the staff, to develop and program information retrieval queries that reflect priority intelligence requirements, and to program automatic data transfers between and among higher, lower, and adjacent echelons. These results provide insights to the complex nature of collaboration and recommendations for further research with respect to training and technologies supporting C2.

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